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**MEASURED EFFECTS OF TACTICAL SMOKE AND DUST ON PERFORMANCE
OF A HIGH RESOLUTION INFRARED IMAGING SYSTEM**

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I. INTRODUCTION

For centuries armies have relied on clouds of smoke and dust to screen their activities from the enemy. These obscurants have consisted both of those deliberately produced for that purpose, such as tactical smoke, and those produced by exploding shells, burning equipment, vehicular motion, and other normal battlefield events. Until recently the screening effects of such obscurants were only of importance in the visible portion of the spectrum. The introduction to the battlefield of electro-optical imaging systems, laser range finders and designators, and passive electromagnetic homing devices, most of which operate in the infrared portion of the spectrum between 1 and 12 microns, makes it of vital importance to determine the performance of these devices in the presence of obscurants.

The high interest in characterizing the performance of tactical E-O equipment in the presence of obscurants has led to a number of "Smoke" measurement programs being conducted in recent years, in which the obscuration effects of various materials, produced under controlled conditions, have been tested on various systems. One such test titled, "Battlefield Induced Contamination Test," (BICT), was conducted at White Sands Missile Range, NM during April and May, 1981 by the Atmospheric Sciences Laboratory (ASL) of the US Army Electronics Research and Development Command.

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The Mobile Tracking Imaging Radiometer (MTIR), an instrumentation system being developed by the Instrumentation Directorate, WSMR, to support future High Energy Laser tests at the Range, participated in BICT at the request of ASL. The MTIR consists of a two-channel (3-5 and 8-12 micron serial-scan, Forward-Looking Infrared imaging system (FLIR) mounted on a servopedestal attached to an instrumentation trailer.

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II. HARDWARE DESCRIPTION

Two-Channel FLIR: The chief sensor of the MTIR is a serial-FLIR built by Honeywell Radiation Center (1). The FLIR is capable of producing imagery simultaneously in the 3-5 and the 8-12 micron bands. The scanner is located behind a 17-inch diameter, 84-inch focal length telescope which gives the system an instantaneous field-of-view of 60 microradians. Full field-of-view of the system is approximately 0.5 degree. The image from the telescope, after passing through the scanner, is split by a dichroic beam splitter to the 3-5 and 8-12 detectors. The minimum resolvable temperature is approx. $.2^{\circ}\text{C}$ at 8-12 micron and 3°C at 3-5 micron (at 1 cycle/mr.). The detectors, which ride on a motorized table for focusing, are cooled by Joule-Thompson devices utilizing high pressure nitrogen gas. Each channel of the FLIR has two outputs. One output is adjustable in gain and level to produce the best image. The other output is fixed and is set for the best linear operation. Output from the FLIR is in standard video format and may be directly viewed on a standard TV monitor. A cutaway drawing of the FLIR is shown in Figure 1. Figure 2 is a photograph of the MTIR system.

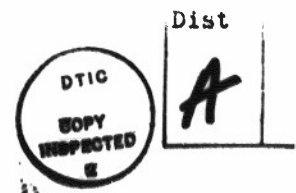
TV Boresight System: A standard TV camera, equipped with a 6 to 1 zoom lens, is mounted above the FLIR system.

Recorders: Five Sony video cassette recorders are rack mounted in the trailer. All video outputs from the FLIR and the boresight TV camera may be simultaneously recorded. The recording system also includes an Ampex, studio-quality, reel-to-reel video recorder. A video matrix switch allows easy routing of the various video signals to selected monitor recorders.

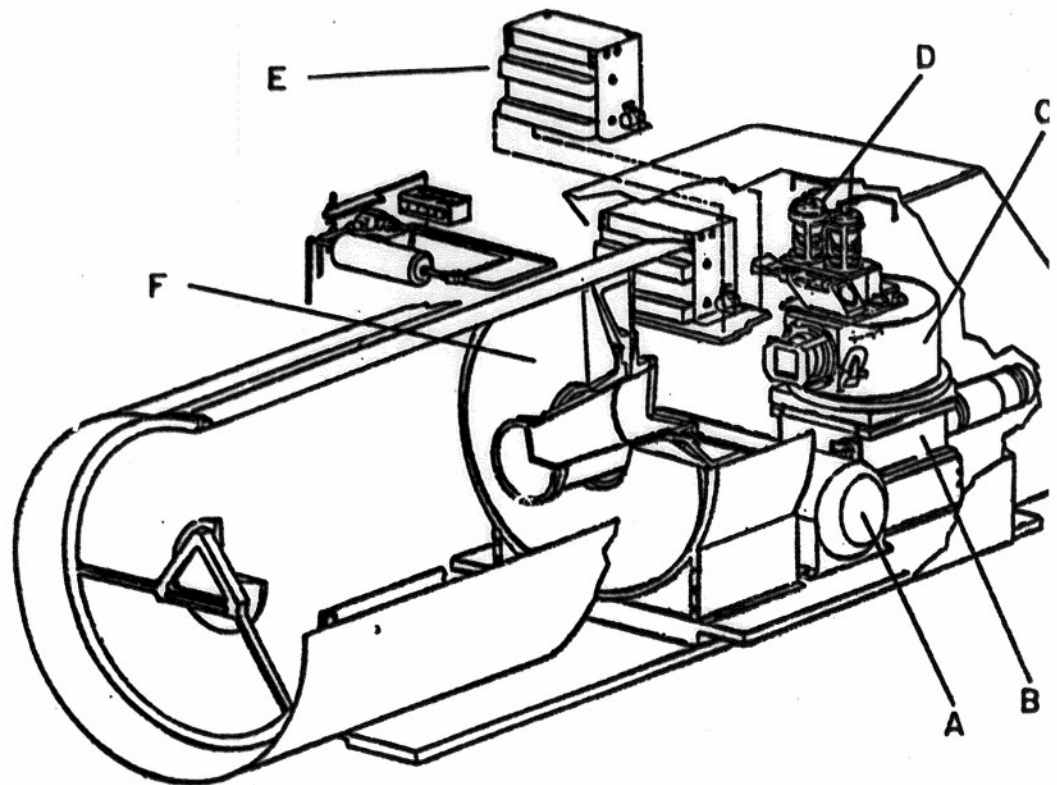
Blackbody Target: A heated, 18 by 18 inch, blackbody, mounted on a trailer serves as the MTIR's calibration target. The target has a temperature uniformity of 1°C and a temperature range of 40 to 500°C . Figure 3 is a photograph of the target.

III. TEST DESCRIPTION

Field Layout: The BICT tests were conducted at the Dusty Infrared Test I (DIRT I) site, located in the far SE corner of WSMR, 30 miles from 14 April through 13 May 1981. The test site consists of a 1 mile north-south optical path with instrumentation pads at each end. A 200 by 300m cleared area, midway between the ends of the optical path, was utilized for the production of smoke and dust (2, 3). The MTIR was located at the south end of the optical path alongside of ASL's LIDAR van. The MTIR's blackbody target was located 600m to the north, at the beginning of the tests. Later it was moved to the northern end of the optical path.



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|-----------------------------|--------------------------|
| A. Nitrogen Bottle | D. Detector Packages |
| B. Motor-Driven Focus Table | E. Pre-Amplifiers |
| C. Scanner Housing | F. 17-in. Primary Mirror |

Figure 1: Cutaway Drawing of Two-Channel FLIR.

when it was feared that it would be damaged by shrapnel. The backs utilized by the LIDAR to reflect 1.06 micron energy from its YAG laser back to its receiver, was also located at the northern end of the path. Figure 4 is a sketch (not to scale) of the field configuration.

Smoke and Dust Generation: Five series of smoke tests were conducted during the BICT tests. These were: The production of hexachloroethane smoke from ignited M1 and M2 canisters, the detonation of canisters containing XM825, a developmental long-duration smoke producing device containing felt wedges saturated with white phosphorus, static firing of pole-mounted projectiles containing bulk white phosphorus (WP), the firing of 155mm white phosphorus shells fired into the test area by two M1 howitzers (LF), and Fire Products, the production of smoke from burning

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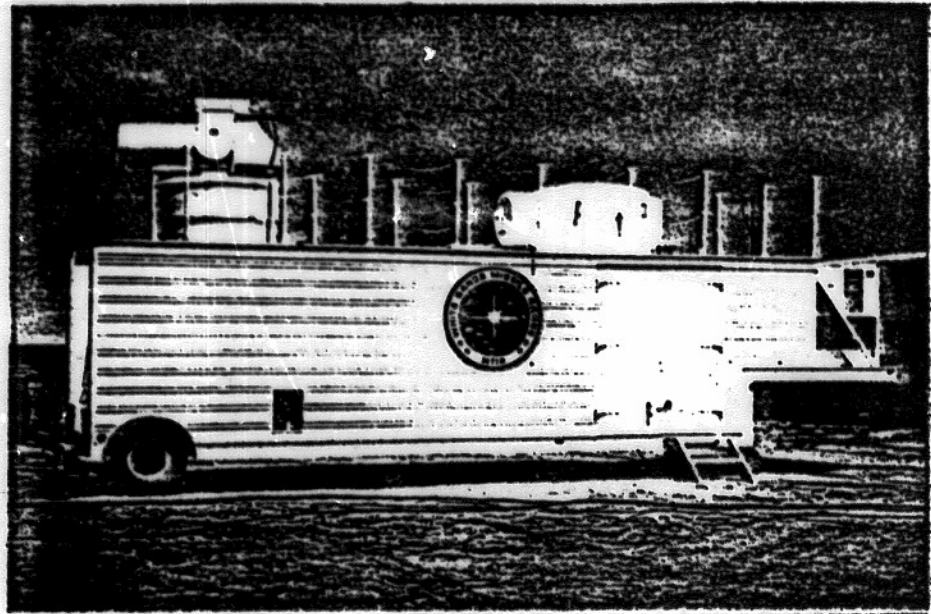


Figure 2: Mobile Tracking Imaging Radiometer (MTIR)

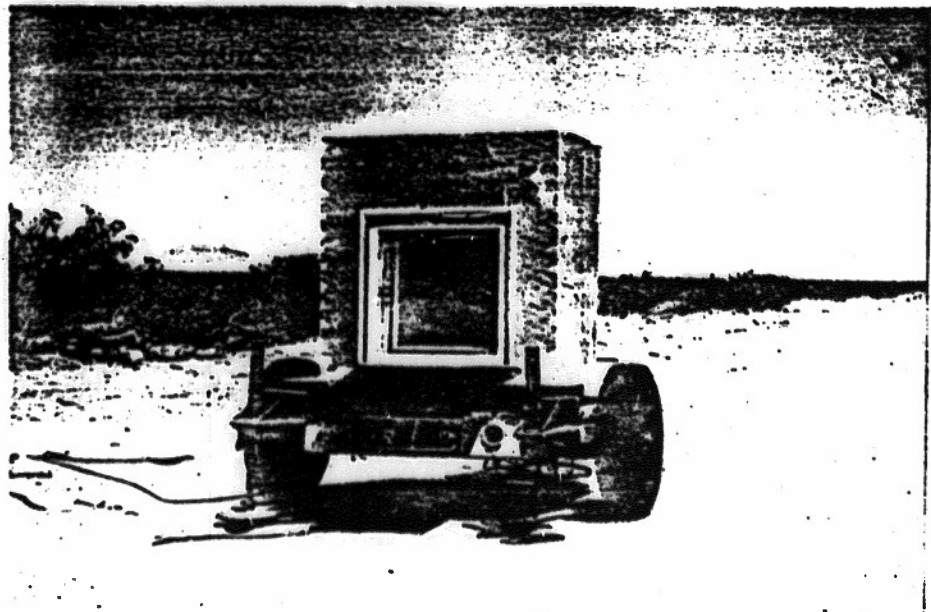


Figure 3: Trailer Mounted Blackbody Target

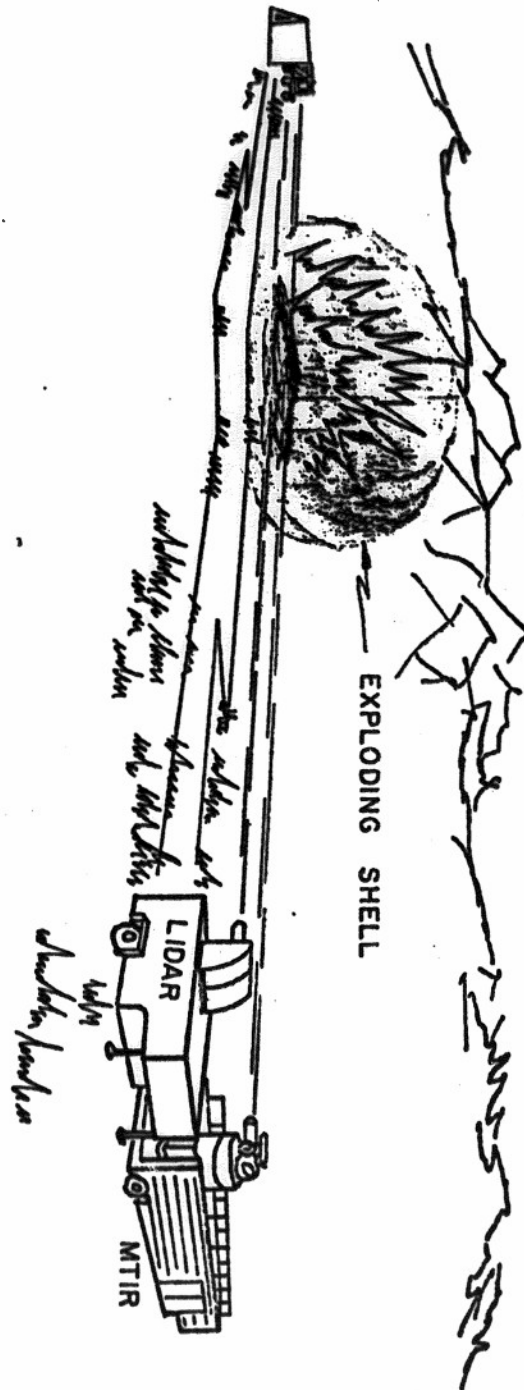
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FIGURE 4. FIELD TEST CONFIGURATION FOR IR TRANSMISSION
AND CONTRAST MEASUREMENTS



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tires and diesel fuel.

Dust clouds were produced in the test area by running tactical vehicle racetrack patterns at distances from 13 to 27 meters to one side of line-of-sight. M-47 tanks, armored personnel carriers, and shop trucks were utilized.

Data Collection: Data was collected by the MTIR during all of the series with the exception of the Fire Products test when it removed support a High Energy Laser test off-range. Data collection consisted of aiming the FLIR at the blackbody target, which was heated to approximately 70°C to simulate a vehicle warmed by engine heat, and simultaneously recording the FLIR output channels and the standard video image before, during the smoke, or dust, cloud development. Timing was inserted between linear outputs of the FLIR and video camera for later data correlation.

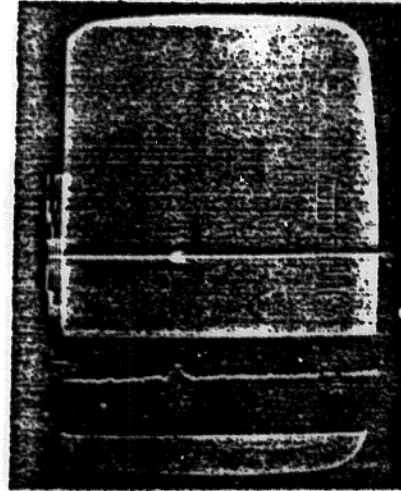
Data Handling: For analysis purposes the imagery recorded on the cassettes was transferred to the Ampex recorder, which has an excellent single frame capability. The image intensity of the heated blackbody, the cool, low emissivity housing of the blackbody were read, at one second intervals, utilizing a Colorado Video Model 321 video analyzer. The ratio of the two readings, the image contrast, was plotted, along with the transmissivity data obtained from ASL, as a function of time (4). Since the dust clouds produced during the tests stayed close to ground level and did not sufficiently intercept the LIDAR's backstop reflector, the contrast of a white building to its dark background was read from the standard video camera output for comparing this part of the test.

IV. RESULTS

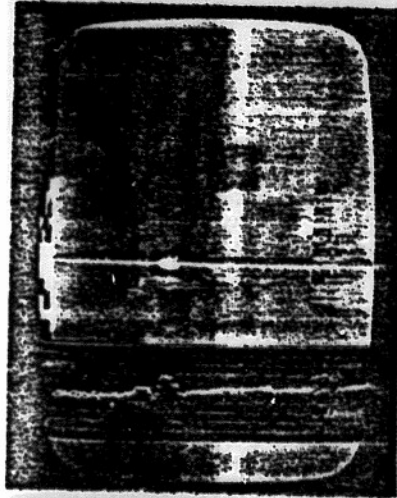
The TV monitor photographs of Figures 5 and 6 illustrate the results of imagery recorded during the tests. The photos on the far left of Figure 5 were taken from the MTIR's video camera and show the scene looking north along the optical path during test HC-7, both before and during development of the smoke cloud. The cross hairs cover the blackbody target position. The large white rectangle in the background is the backstop. The photos in the middle and to the right are from the FLIR 8-12 and 3-5 channels respectively and show the excellent HC smoke penetration at these wavelengths. These photos were taken after passing FLIR signals through the video analyzer. The white rectangle near the middle of the vertical line is the heated blackbody target. The photos of Figure 6 were taken at the start of test WP-10. The white area in the upper right of the video camera image (upper photo) is an exploding bulk phosphorus shell. The lower photo is an 8-12 micron image recorded seconds later and shows a low jet of hot smoke, almost invisible in the video image, about to obscure the target. The detonation is not visible.

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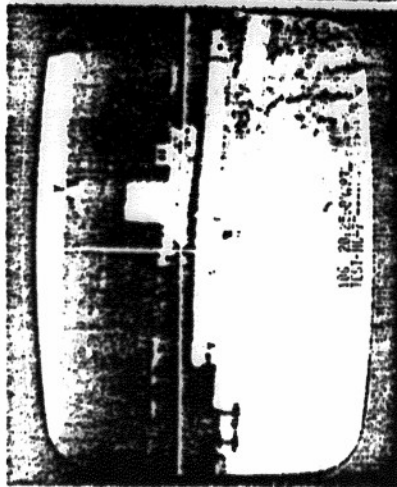
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3-5 Micron



8-12 Micron



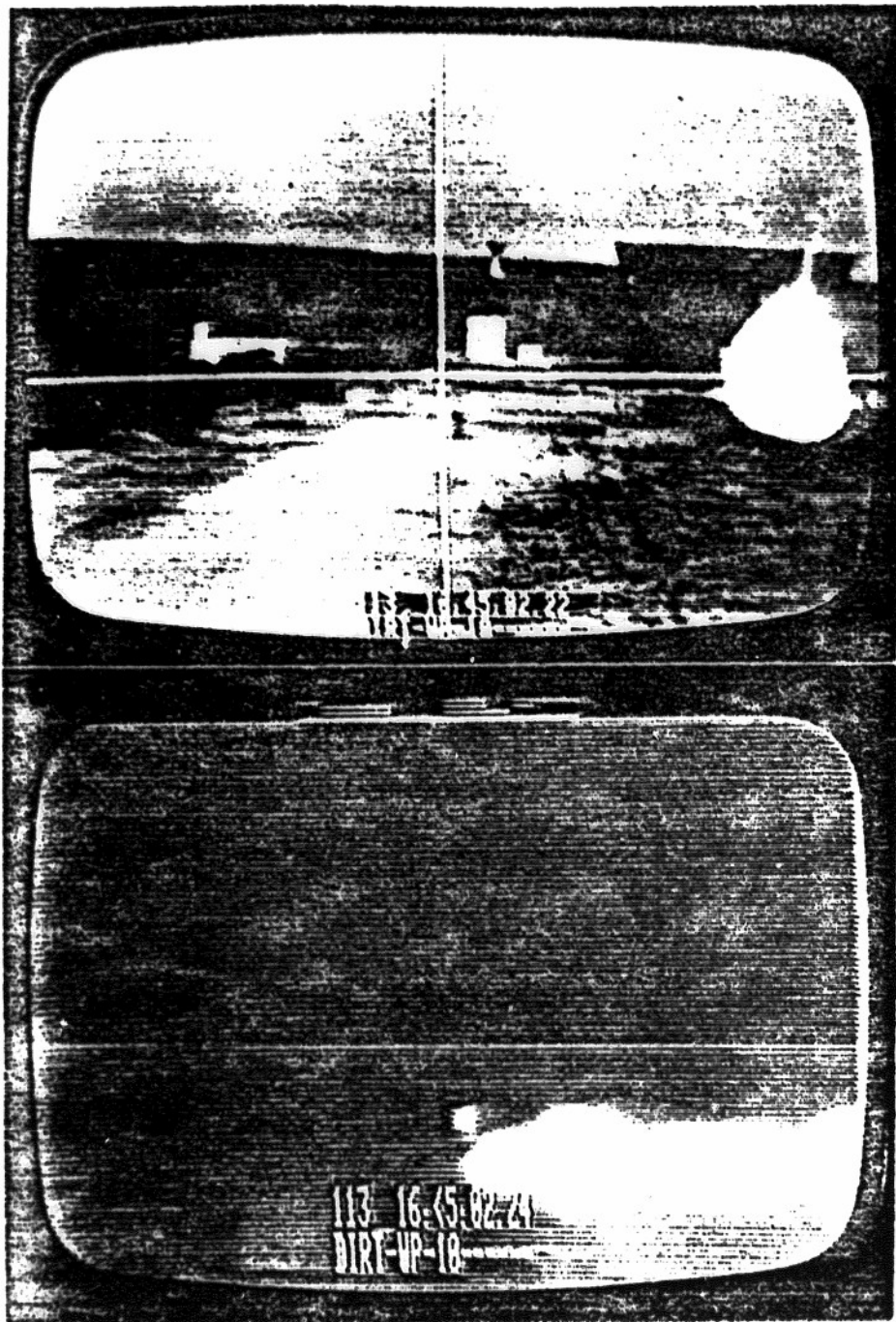
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Video

8-12 Micron

Figure 6: Explosion of a White Phosphorus Shell During Test WP-10.

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in the 8-12 micron image due to the FLIR's smaller field-of-view.

Figure 7 is a plot of FLIR image contrast and 1.06 micron transmissi versus time for test HC 11. The sharp drop in the transmission curv dicates the arrival of the smoke cloud in the optical path. Figure presents data recorded during tests XM-10. While contrast reduction apparent in the FLIR images early in the test at no time was the ta completely obscured in either IR band. It is interesting to note th 3-5 micron image, while of lower contrast due to the lower sensitivi the FLIR in this band, seems less effected by the XM smoke than does 8-12 micron imagery. Figures 9 and 10 show data recorded during tes WP-10 and LF-4. Both of these tests involved the explosion of bulk phosphorus shells. Total obscuration of the target, in both FLIR ba was experienced during test WP-10 for an extended period of time. T nearness of the WP detonations to the optical path resulting in hot in the line-of-sight is partly responsible for the total loss of con During test LF-4, smoke from two WP rounds drifted across the optica path. Image contrast was lost only briefly at 8-12 micron and for 1 periods at 3-5 micron.

Figure 11 compares the contrast of visible and 8-12 micron imagery t dust raised by two armored personnel carriers running in a racetrack pattern west of the optical path. Soil dampness inhibited the format of dust clouds thick enough to completely obliterate the visible cont during most of the test. The 8-12 micron contrast curve closely foll that from the visible imagery and indicates some dust penetration potential.

V. CONCLUSIONS

cont Results of the tests show that ~~the~~ smoke screens do not effec ly screen against infrared imaging systems operating in the 8-12 and micron bands. Contrast is reduced, but not obliterated in either ban XM smoke. Smoke produced by the explosion of bulk white phosphorus s is effective in blocking FLIR imagery if the detonation takes place n enough to the line-of-sight so that the smoke is hot. Dust Clouds ar effective obscurants in the 8-12 micron band. *hexachloroethane*

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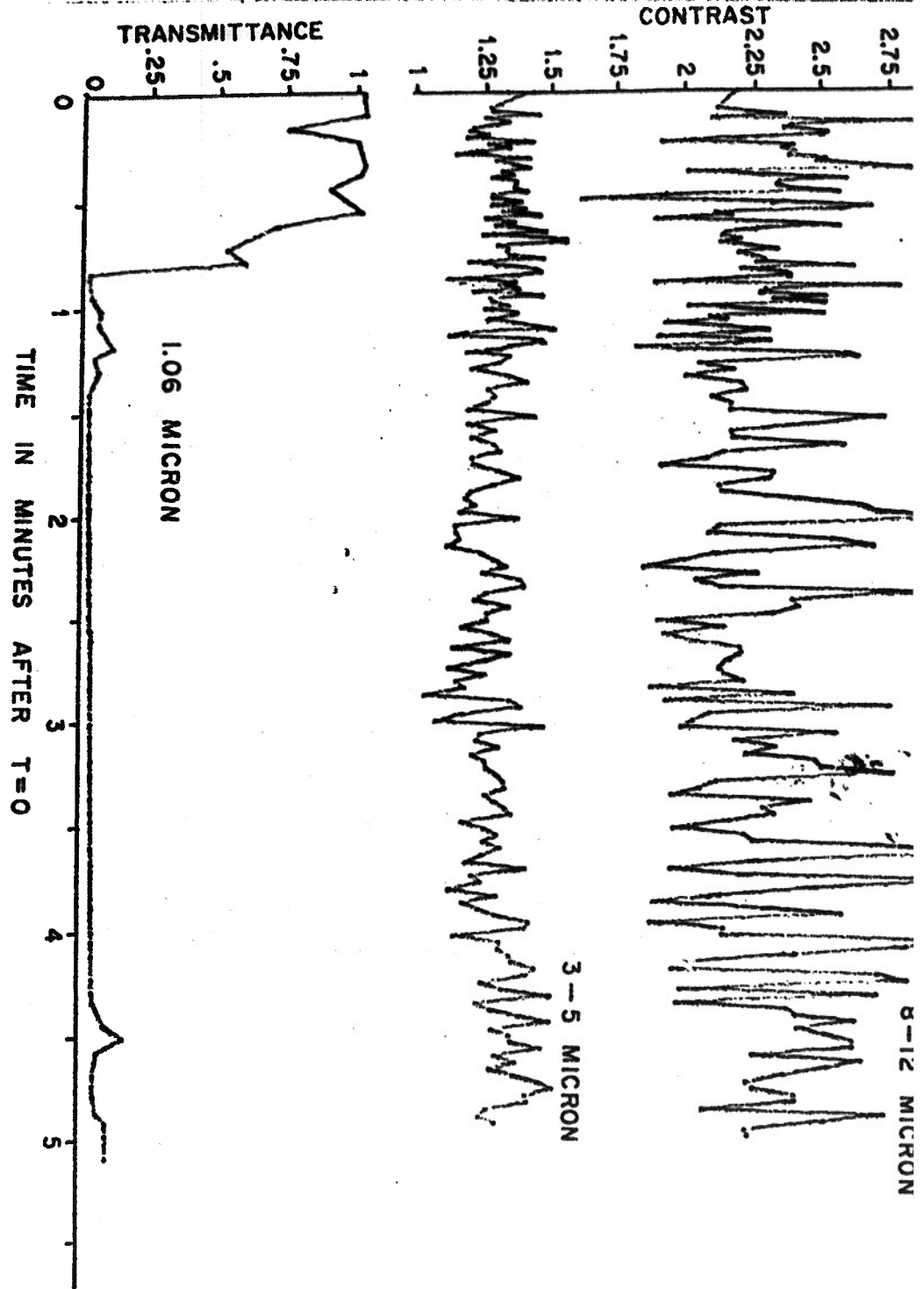
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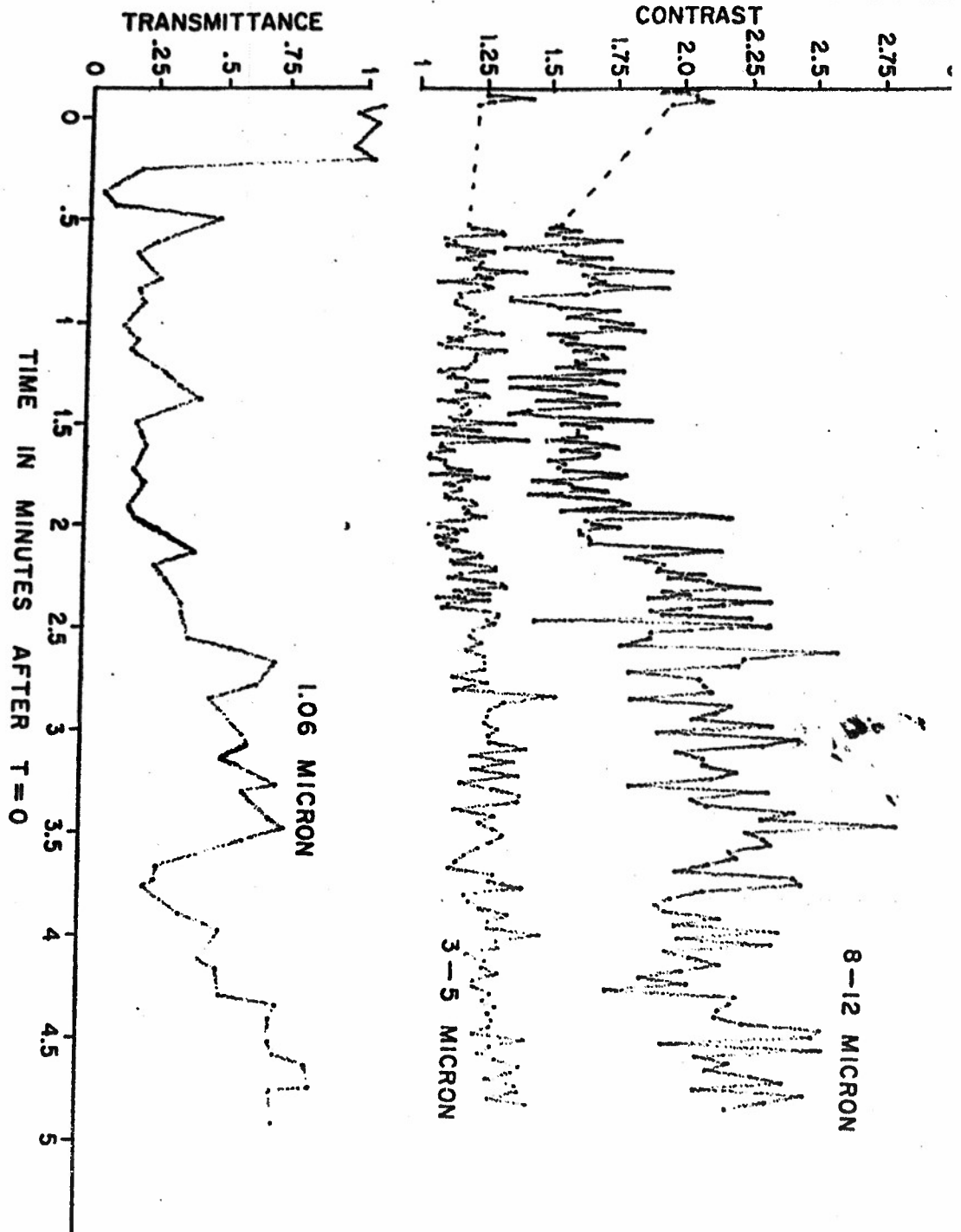


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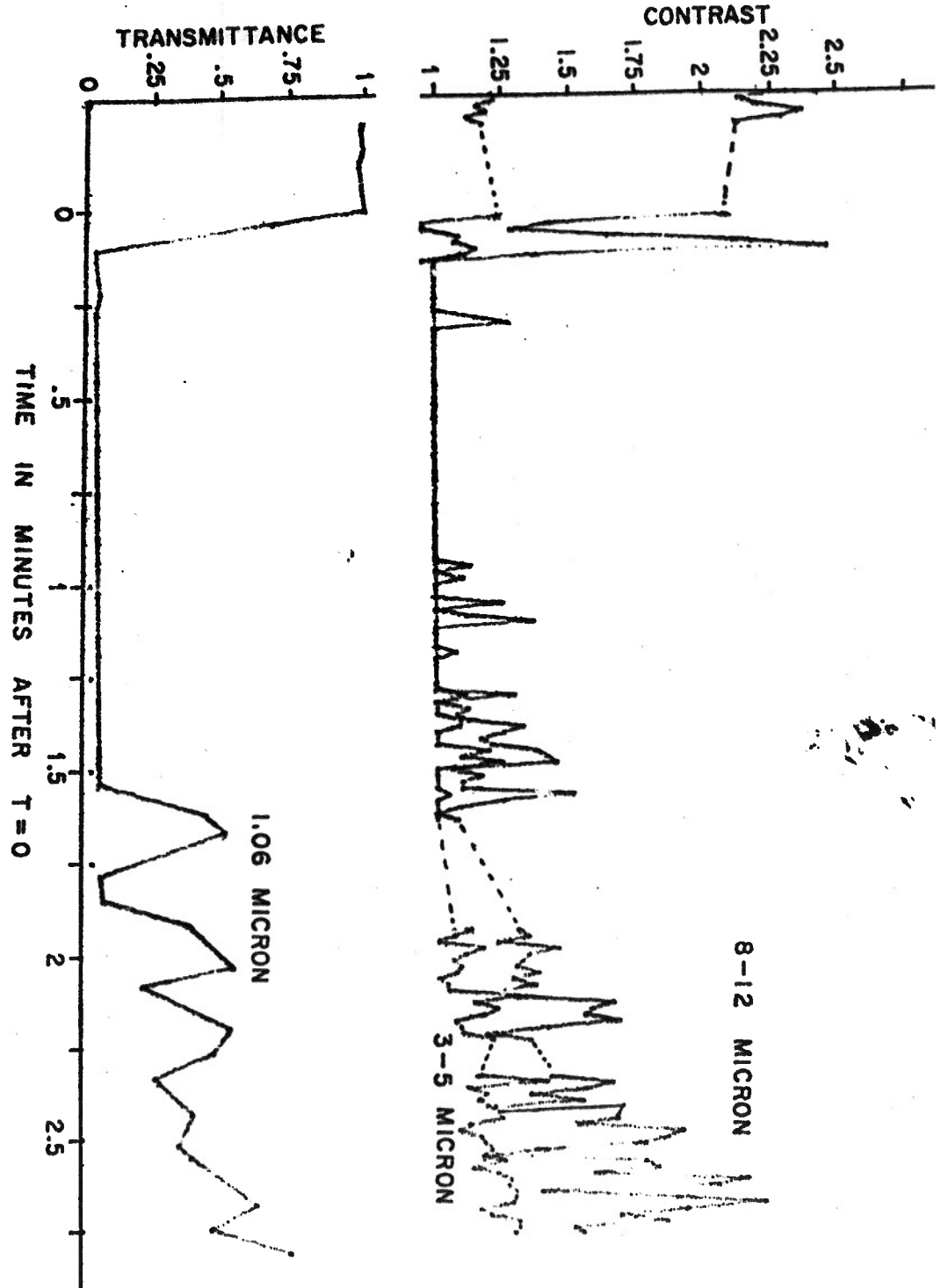


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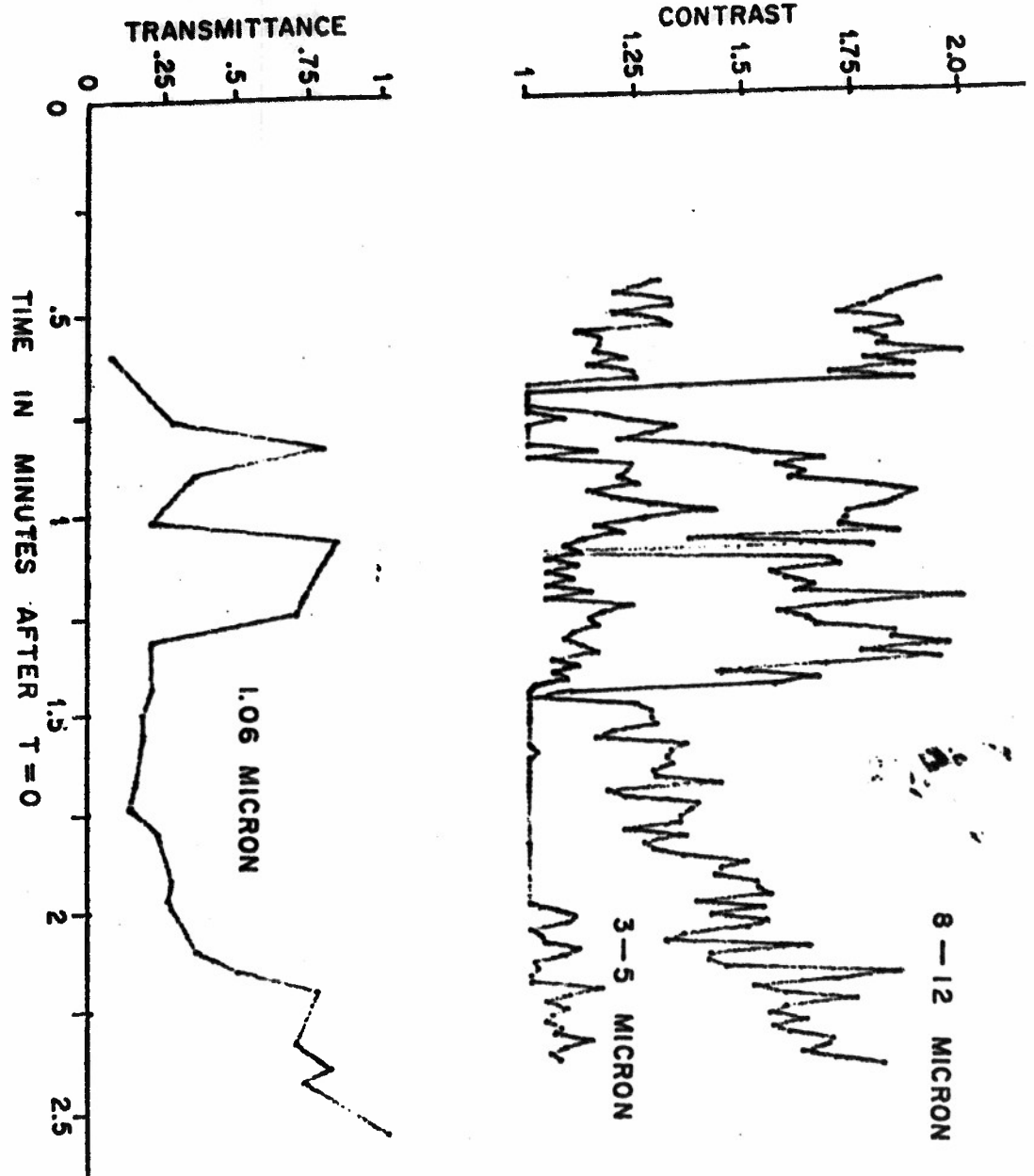


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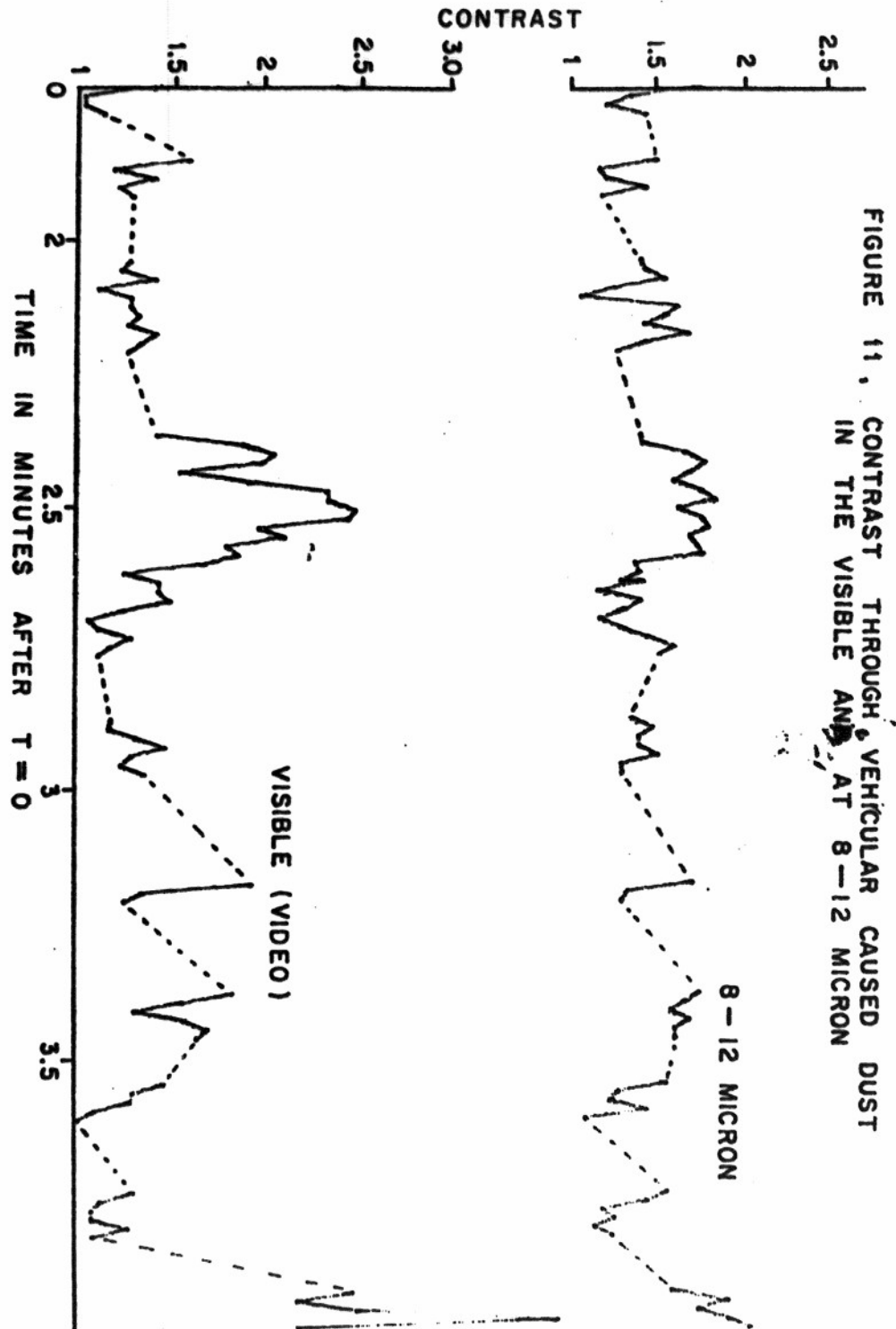


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